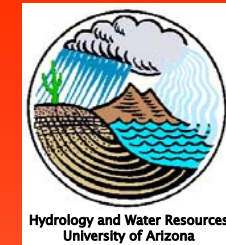


Monsoon Season Surface Water Chemistry Response Following Wildfire: 2003 Aspen Fire in Sabino Canyon, Arizona (#H41D-1037)

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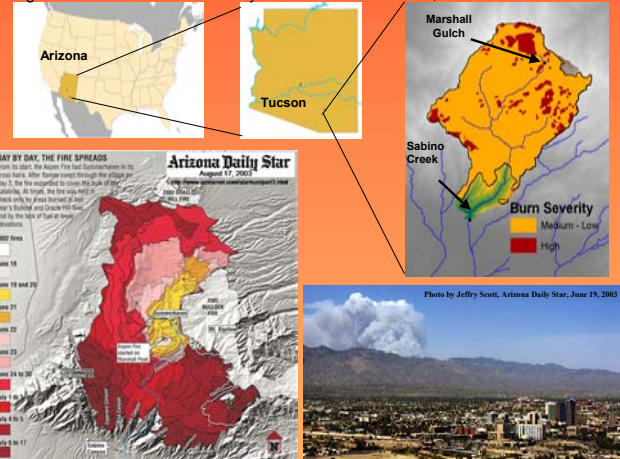


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SITE DESCRIPTION

During June and July of 2003 the Aspen Fire in the Coronado National Forest north of Tucson (Figure 1) burned in excess of 80,000 acres and destroyed more than 300 structures (Arizona Daily Star, August 17, 2003). The portion of the watershed that has been burned by the Aspen fire covers a wide range of elevation and vegetation zones of the Santa Catalina Mountains. Many biogeochemical and hydrological processes within this area were altered by a sudden lack of vegetation and changes in soil properties following a fire: evapotranspiration, litter volume, organic decomposition, leaching, cation exchange, anion sorption, nutrient uptake, and soil hydrophobic layers.

Figure 1. Location of Sabino Canyon Watershed in Tucson, AZ



SUSPENDED SEDIMENT TRANSPORT

Samples were taken to capture the hydrograph behavior for several flood events in Sabino Creek, which drains the main watershed burned by the Aspen Fire. The "flashy" response of Sabino Canyon created logistical challenges to correctly time sample collection to capture baseflow immediately prior to flooding and the flood peak. The best-characterized hydrograph was the monsoon-driven flood event on September 9, 2003.

The total suspended solids (TSS) measurements from this hydrograph, collected at the USGS Gauge station, were used to estimate sediment transport from the basin during the flood. This was done by interpolating between the collected samples to 15-minute increments that match the flow data and then integrating the flow (m³/s) * TSS (kg/m³) over time to yield a total suspended sediment transport mass: 2249 kg.

In order to estimate the sediment removed from the other flood events, a relationship was developed between the flow rate and TSS (Figure 1c). This correlation was applied to the flow data from the previous floods and the same integration was performed to obtain the values listed in Table 2. As a quick check on this method, the TSS-flow correlation was used to re-calculate a value for the 9/9 flood: 2427 kg. The difference between the measured and calculated values is 7.3%.

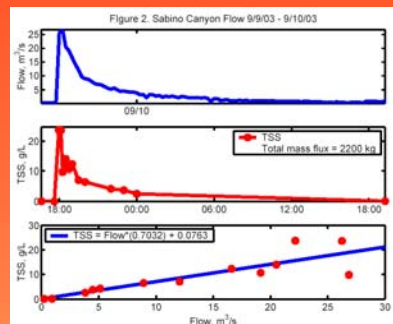
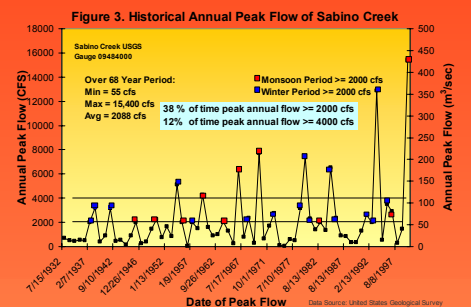


Table 1. Calculated sediment transported from the basin during monsoon flood events using the TSS-Flow relationship.

Hydrograph start/end	Peak flow (m ³ /s)	Suspended Sediment transported (kg)
7/22/03	7/24/03	23
7/24/03	7/26/03	57
7/27/03	7/29/03	5
7/29/03	8/1/03	18
8/7/03	8/9/03	4
8/18/03	8/20/03	8
8/23/03	9/2/03	111
9/8/03	9/13/03	27
9/14/03	9/23/03	1
9/23/03	10/4/03	7
10/4/03	10/26/03	7
TOTAL		62,991

* Value in parentheses from measured TSS data.



This picture of water spilling over one of the roadways in Sabino Canyon Recreation Area shows the "blackwater" typical of the floods following the fire. Picture by Friends of Sabino Canyon.

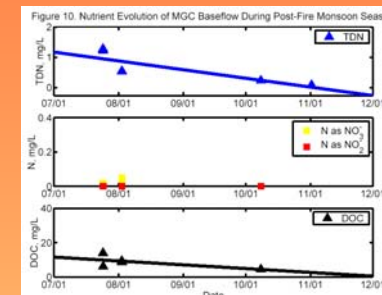
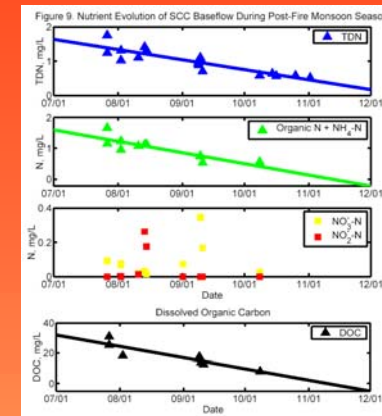
Ash deposit in Sabino Creek is 1/2 to 3/4 inch deep.

NUTRIENT CYCLING: EVOLUTION OF THE BASEFLOW

Baseflow samples were collected in Sabino Creek and Marshall Gulch Creek between flood events to assess the gradual system recovery after the fire. The sudden conversion of vegetation and litter to ash created a large pool of normally stored nutrients and elements that could be rapidly mobilized within this watershed. We observed an immediate increase over pre-fire levels in dissolved nutrients, total dissolved nitrogen (TDN), and dissolved organic carbon (DOC) that linearly decreased with time (Figures 9 - 10). The progressive decrease over time suggests a gradual washing out of these nutrients and anions and a watershed system recovery to base levels. However, the loss of these nutrients, that normally would be stored within the soil for later uptake by new growth, may slow post-fire vegetation recovery rates.

For Sabino Creek, nitrogen exists predominantly in the organic form, with only small amounts of ammonia, nitrate, and nitrite present. The behavior of the nitrate and nitrite, the first peaking in August and the other in September, was a surprise. Typically nitrite is a transient phase and was unexpectedly high considering the concurrently low nitrate values. Nitrification could be occurring; however, the displacement of peak timing is difficult to explain. In general, high concentrations of DOC and TDN are expected after the fire and their progressive removal could also indicate a rise in microorganism activity due to the availability of otherwise limiting nutrients.

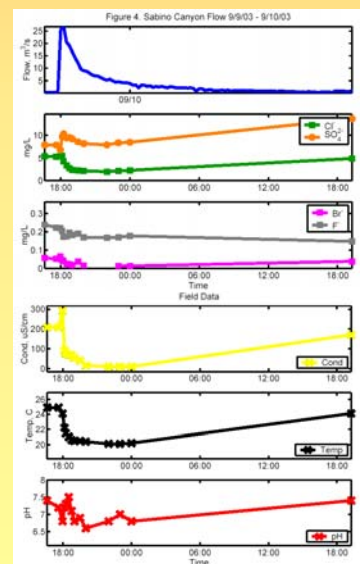
For the baseflow of Marshall Gulch Creek, a similar linear decreasing trend with time was observed for nitrogen, carbon, and sulfate. Again, the predominant form of nitrogen was organic, and here the maximum amounts of nitrate and nitrite are an order of magnitude smaller than the downstream Sabino Creek samples. This may be due to the close proximity of Marshall Gulch to the spring water source. One unexpected trend was a persistent increase in chloride concentrations; this was not observed in the Sabino Creek.



ABSTRACT

As part of an integrated investigation of the hydrologic impacts of this fire, we rapidly mobilized a field sampling campaign during the 2003 monsoon season that began immediately following the resolution of the fire. Stream water chemistry serves as an integrated signal of many watershed processes: precipitation, runoff, infiltration, soil hydrophobic layers, ash deposition in the stream, debris flows, and subsequent water/ash chemical equilibrium reactions. Surface water samples were collected following an event-based sampling strategy, while soil samples were collected in each vegetation and burn severity regime. Precipitation samples were collected to characterize temperature and elevation effects on stable isotope precipitation values. Exposed, burned soils are highly vulnerable to intense summer monsoon rains, leading to increases in surface runoff, peak flows, and erosion rates. Both nutrient and suspended sediment loads greatly increased following the fire. A debris flow mobilized large diameter boulders. During the post-fire monsoon season a flow event peak already surpassed the historical threshold established for this gauge station placing this season within the rare (12%) grouping of highest flood years on record (Figure 3).

OVERLAND FLOW VS. GROUNDWATER: CONCEPTUAL MODEL & MIXING CALCULATIONS



To capture the fire-affected stream chemistry behavior during a flood event, samples were collected prior to, during, and after the monsoon storm on September 9, 2003. The storm duration was approximately 4 hours (12:40-16:50) and the average precipitation was 0.8 in (2 cm) for the mountain (elevation 2700m) and 0.12 in (0.3 cm) at Sabino Canyon Dam (elevation 825 m) where the samples were obtained (Pima County Flood Control District Alert Flood Warning System). From the anion, isotope, and field parameter data it is observed that the rain input, predominantly at the top of the mountain, creates a pressure pulse that pushes out a mix of groundwater and overland flow (Figures 4 and 5). Initially, and notably during the flow peak, the pulse is predominantly the local groundwater; gradually the influence of the overland flow increases.

Mixing calculations were done using the isotope and chloride data to determine the percentages of overland flow and groundwater. The groundwater end member for both parameters was determined as the average value of the baseflow samples taken prior to the flood. Stable water isotope data was available for precipitation in Tucson on 9/8/03 and 9/10/03 (Eastoe, Pers. Comm.). These isotope values were volume corrected for elevation with a hypsometric curve of the watershed (Figure 7) and precipitation data from four rain gauges on the mountains (Figure 6). The decrease in the Tucson rain isotope value from 9/8 to 9/10 is believed to primarily result from the decreasing influence of evaporation as the rain falls through the low humidity atmosphere on the first day of rain (9/8). The relative humidity increased for the region and stabilized before the precipitation on 9/9 and remained similar through 9/10. The rain end member for 9/9 is expected to be similar to that for the sample collected on 9/10.

The calculated precipitation end member value does not fall along the line from the surface water event samples (Figure 6). This could be from an error in our assumptions to determine the rain value for 9/9, or it could indicate an additional end member. Further analyses of additional hydrographs will be necessary to confirm the presence of a third end member. For this mixing calculation, it is assumed that there are only two end members and the value from 9/10 was determined by adjusting the 9/10 data point perpendicularly so that it falls on the event line.

The results of the mixing calculation are shown in Table 2. The maximum contribution of overland flow is 62%. If we are generous with our uncertainty of the precipitation end member and assume the most depleted surface water measurement represents 100% precipitation then we obtain a maximum error of 40%. Under this assumption the maximum contribution of overland flow is 82± 18%. For the chloride, the rain end member was taken to be an average value for southern Arizona (Langmuir, p.280). The results from this mixing calculation are also shown in Table 2, with a maximum contribution of overland flow of 66%. The independent chloride mixing calculations lend support our calculated precipitation end member.

Again it is noted that the bulk of the flow (see peak position), is through the groundwater system rather than runoff. Integrating the volume fraction of the groundwater and overland flow for this flood event yields 242,000 m³ and 129,000 m³, respectively.

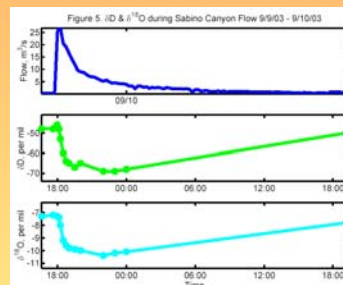


Table 2. Volume Fraction Analysis with Cl and δD

SC03-3	Cl (mg/L)	VF _{Cl}	VF _{iso}	δD (‰)	VF _{Cl}	VF _{iso}
SC03-3	5.4	1.00	0.00	-48	1.00	0.00
SC03-4	5.4	1.01	-0.01	-46	1.06	-0.06
SC03-5	5.5	1.04	-0.04	-48	1.00	0.00
SC03-7	4.3	0.80	0.20	-53	0.85	0.15
SC03-8	3.4	0.61	0.39	-60	0.65	0.35
SC03-9	2.8	0.49	0.51	-64	0.53	0.47
SC03-10	2.4	0.42	0.58	-65	0.50	0.50
SC03-11	2.2	0.38	0.62	-67	0.44	0.56
SC03-12	2.2	0.38	0.62	-65	0.50	0.50
SC03-13	2.0	0.34	0.66	-69	0.38	0.62
SC03-14	2.2	0.38	0.62	-69	0.38	0.62
SC03-15	2.3	0.40	0.60	-68	0.41	0.59
SC03-16	4.9	0.91	0.09	-50	0.94	0.06

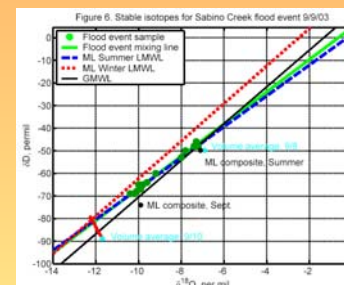


Figure 7. Hypsometric curve for Sabino Watershed

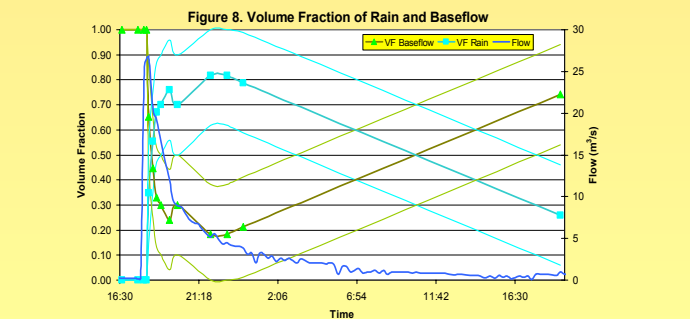
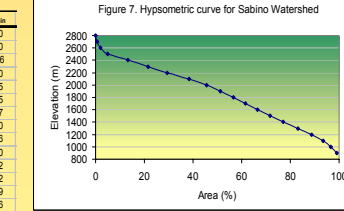


Photo: Aaron J. Latham (Arizona Daily Star August, 19, 2003) Karletta Daane Chief, left, collects a soil sample with Maite Guardiola.

Photo by Karletta Chief

Photo by Kazungu Maitaria

CONCLUSIONS

1. Post-fire flash flooding from the 2003 monsoon season transported 65,000 kg of suspended sediment from the Sabino Watershed.
2. High levels of nitrogen and carbon were observed in the immediate post-fire runoff events; these concentrations decreased by a factor of two within three months of the fire resolution.
3. Stable water isotopes were used to estimate the individual contributions of precipitation runoff and baseflow to a flash flood event. The ratio of groundwater to overland flow was determined to be approximately 2:1.

FUTURE WORK

The surface water chemistry changes measured throughout each hydrograph event will be linked to concurrent air permeability results, a rapid measurement for soil hydraulic conductivity, for the different burn severity and vegetation zone regimes (see Poster H42G-1157).

Observations from the burned area will be compared with unburned and historical measurements for quantification of the fire impact on the watershed geochemistry.

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SABINO CREEK

MARSHALL GULCH